6. The astronomical refraction depends upon the physical density of the air, and not, as before assumed, upon the optical density.

7. Granting 6, then the Munich observations do not demand a change in the adopted value of the coefficient of expansion of air. A result which agrees with other (not all) recent investigations, laboratory as well as astronomical.

8. The Munich observations, as well as others, show the necessity of a considerable decrease in BESSEL'S constant of refraction.

PROGRAMME OF THE INTERNATIONAL GEODETIC ASSOCIATION FOR OBSERVING VARIATIONS OF LATITUDES.

By FRANK SCHLESINGER.

The twelfth General Conference of the International Geodetic Association was held at Stuttgart, in October, 1898. A plan that had been under contemplation for several years for observing variations of latitudes was there formally adopted. Since then the observations have actually been begun and some of the details of the work may not be without interest.

I. SELECTION OF THE STATIONS.

The general aim of the association was to establish four stations on the same parallel of latitude, as well distributed in longitude as possible; to equip these stations with zenith-telescopes embodying some modifications that previous experience has indicated, and of larger aperture than usually employed; to so arrange the programme that all the observations at one station could be made by a single observer. It was of course necessary that each station should be located where there was a good average of clear nights, not only for the whole year, but for each season, in order to guard against a long interruption of the observations. It was deemed desirable that the character of the country should be the same to the north and to the south of each station, and that the seismological, hygienic, and social conditions should be good. With all these requirements to be considered,

it was by no means an easy task to select four suitable sites. After discussing many possible combinations of locations, the Central Bureau of the association finally fixed upon the following:—

	Longitude West of Greenwich.
Mizusawa, Japan, ...	-141°
Carloforte, Italy, ...	-9°
Gaithersburg, Maryland, .	$+77^\circ$
Ukiah, California, ...	$+123^\circ$

Mizusawa* lies in the valley of the Kitakami River, and has a population of ten thousand. The station is half a mile south of the city, in latitude 39° 08′ 07″. Carloforte has eight thousand inhabitants, and is the principal city on the small island of San Pietro, which lies just west of Sardinia, near its southern extremity. The latitude of the station will not differ greatly from 39° 08′ 12″. Gaithersburg is a town of two thousand people, about twenty miles northwest of Washington. The station is about half a mile from the town, and is in latitude 39° 08′ 10″. Ukiah is in the valley of the Russian River, and has two thousand eight hundred inhabitants. It is the terminus of a railroad which runs one hundred and twelve miles north from San Francisco, and is about thirty miles from the Pacific Coast; the station is a mile south of Ukiah, in latitude 39° 08′ 09″.

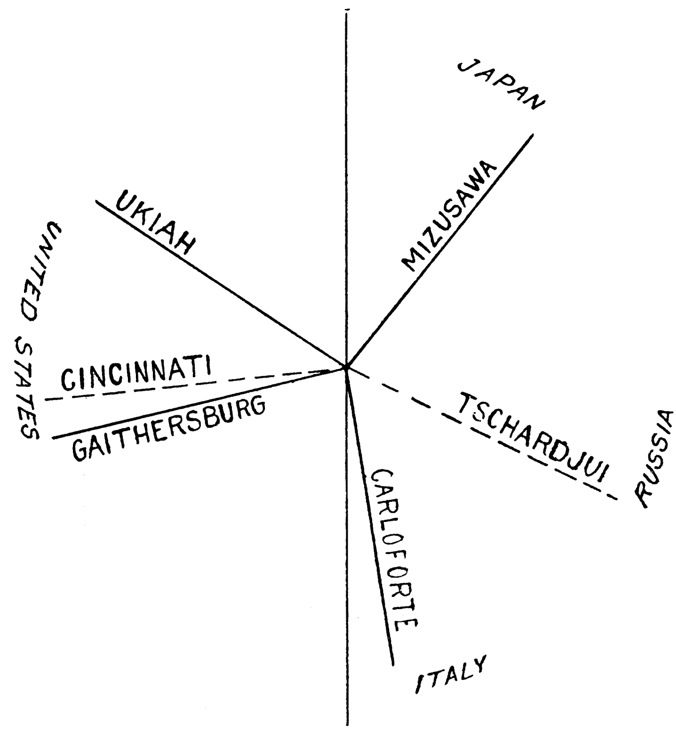
Thus two of the stations are in the United States; and in regard to these, the Superintendent of the United States Coast and Geodetic Survey has agreed to undertake the supervision, an arrangement which has been of the greatest benefit to the work.

The four stations established by the association are within a few seconds of the same parallel of latitude. By a mere coincidence Cincinnati Observatory, which is in longitude 84° west of Greenwich, is only a few hundred feet north of this parallel. The director of the observatory, Professor J. G. PORTER, has volunteered to take part in the programme, an offer which was readily accepted by the International Association. Furthermore, the Russian Government has also offered to equip and support a sixth station at Tschardjui, a city in longitude 64° east, on the River Amu-Daria (or Oxus), and on the required parallel. This addition is especially welcome, as otherwise there would be an arc of 133° between Carloforte and Mizusawa unprovided with a

*The writer is indebted for most of these details to the "Bericht über die Vorbereitungen für den internationalen Polhöhendienst," HELMERT and ALBRECHT, 1898.

station. It may be mentioned here that there is some possibility of the permanent removal to Tschardjui of the observatory which is now at Taschkent.

The distribution of all six stations is shown in the accompanying figure, the central line representing the meridian of Greenwich.



DISTRIBUTION OF THE STATIONS.

II. THE PROGRAMME FOR OBSERVING.

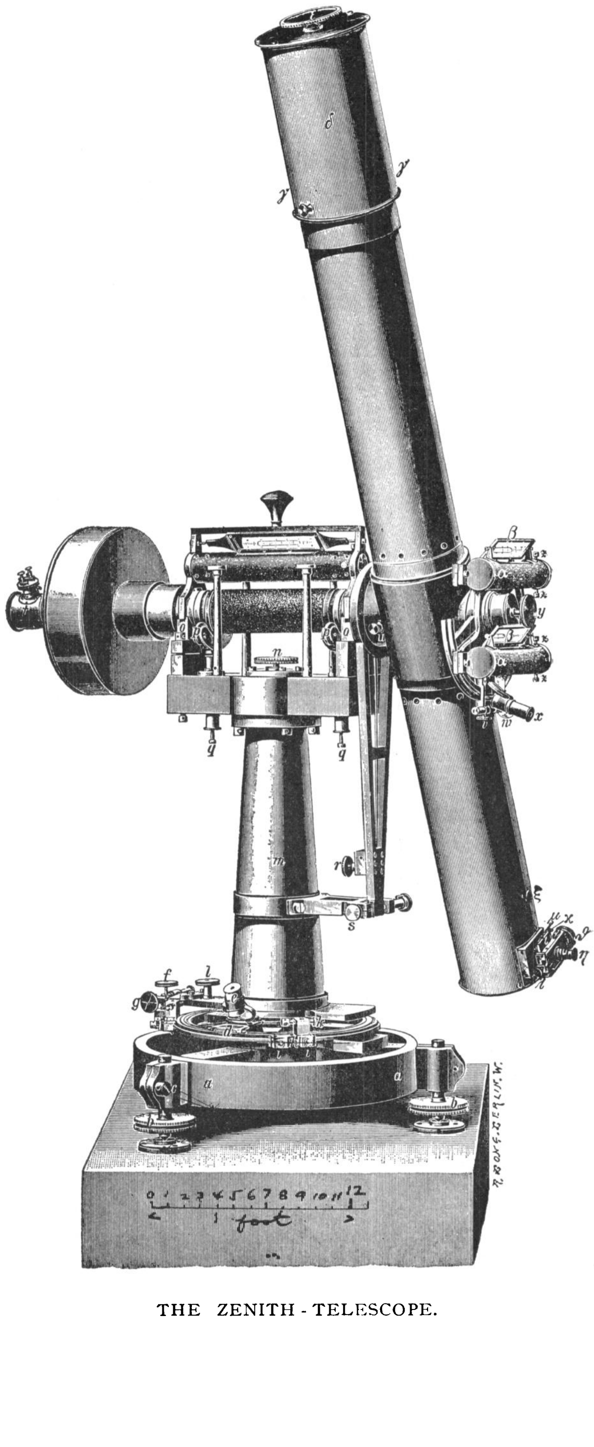
In arranging the programme for observing, the controlling desideratum has been to obtain the most accurate results for the variation of latitude solely, and not to attempt to use the observations for deducing the value of the constant of aberration. Following KÜSTNER'S lead, in which he obtained the first conclusive observational evidence of a change in latitude, most other latitude observers have also sought to determine the aberration constant. Such a plan necessitates a limited number of groups, of which one at least must be observed during nearly the whole of the period in which it transits at night. The accuracy of the

resulting latitudes is thus lessened for two reasons; first, because there are periods when only one group can be observed, and, second, the latitude results will be more dependent upon the value adopted for the aberration constant. This follows from the very cause that would make such a series of observations valuable for determining the constant. The Central Bureau of the Association has decided to use no less than twelve groups, each extending over two hours of Right Ascension. Two consecutive groups are to be observed on each night as follows:—

Group.	R. A.	To be observed From	To	Duration of Group.	Duration of Group Connect'n.
I	$0^h - 2^h$	Sept. 23	Dec. 6	74 days	35 days
II	2 - 4	Nov. 2	Jan. 4	64	29
III	4 - 6	Dec. 7	Jan. 30	55	26
IV	6 - 8	Jan. 5	Feb. 24	51	25
V	8 - 10	Jan. 31	Mar. 21	50	25
VI	10 - 12	Feb. 25	Apr. 15	50	25
VII	12 - 14	Mar. 22	May 11	51	26
VIII	14 - 16	Apr. 16	June 8	54	28
IX	16 - 18	May 12	July 9	59	31
X	18 - 20	June 9	Aug. 13	66	35
XI	20 - 22	July 10	Sept. 22	75	40
XII	22 - 24	Aug. 14	Nov. 1	80	40

By "duration of group-connection" is meant the period in which the same two groups are observed: thus, Groups I and II are observed together during a period of thirty-five days; Groups II and III during twenty-nine days, etc. It will be noticed that these periods are short in the spring and long in the fall. This arrangement was adopted principally for the convenience of the observer, as the night's work is thus brought as nearly after sunset as was deemed safe. In midwinter, observing will begin not less than two and a half hours after sunset, while in midsummer this minimum interval is reduced to one and a half hours.

Each group contains eight pairs, only six of which, however, are to be used directly in determining the latitude. The two others are of very large zenith-distances, and were introduced, upon the suggestion of Professor HELMERT, in order to detect anomalous refractions. In the discussion of previous latitude observations such anomalies have often been appealed to, in order to account for some puzzling systematic discrepancies in the results. It has happened, for example, that the values of the latitudes from all the pairs on a certain night were greater than



THE ZENITH-TELESCOPE.

the true value. This result would be brought about if the index of refraction were greater to the south of the station than to the north. In the present programme such a condition of affairs will be revealed in the observations themselves for any single night, since there will be four pairs at about 60° zenith-distance while the latitude pairs exceed 20° zenith-distance in only three or four cases in all twelve groups.

The observing list therefore requires the selection of ninety-six suitable pairs, a far greater number than has usually been employed. Nevertheless, it has not been a very difficult task to make the selection because the instruments are of large enough aperture to permit the use of stars down to the seventh magnitude; and besides, accurate knowledge of proper motions, or even positions, of the stars is by no means necessary in the present case. A proper-motion effect cannot be confused with a variation of latitude, for the latter at any station has its counterpart, or rather its intaglio, at a station on the opposite meridian. For example, if the latitude of Ukiah should increase, then that of Tschardjui must decrease by practically the same amount, since these two stations differ nearly 180° in longitude. On the other hand, if the increase in the latitude of Ukiah should be only apparent and due to ignorance of proper motions, then the latitudes of all the other stations would be increased by the same amount. The observing list as actually constructed is an admirable one. The stars vary in magnitude from 4.0 to 7.0. The maximum difference of zenith-distances is about 16′ for the latitude pairs, and only about 5′ for the refraction pairs. The least interval between the transits of any two consecutive stars in the list is four minutes, allowing ample time for level readings before and after each transit.

III. The Zenith-Telescope.

Each of the four principal stations has been furnished with an instrument like that shown in the accompanying drawing. Except as to its larger dimensions and three or four other points, this instrument does not differ from those formerly employed, but a brief description may not be amiss. The instrument rests on the three leveling-screws, *b*, on point, line, and plane bearings. The horizontal circle has a diameter of eleven inches, and may be read by means of two verniers to 10″. Upon the circle are mounted two stops, *k*, which, having been set once for all, permit the instrument to be reversed 180° in a few seconds. Most of the weight

of the movable parts is supported by the adjustable springs, q, provided with friction rollers at p. Thus only a slight pressure is exerted upon the wyes, o.

The focal length of the telescope is fifty-one inches, though the tube is nine inches longer on account of the dew-cap, δ, the object-glass being at γ. The aperture is four and one quarter inches; but the tube is again somewhat larger in diameter, because it is double throughout its entire length, with an air-space between its two walls. The outer tube is pierced by a double row of ventilating holes, the idea being to guard against sudden changes of temperature and consequent flexure.

The levels, a, are extremely sensitive; they may be adjusted by the opposing screws, z, and the lengths of the bubbles may be regulated without removing either level from its fastenings. The vertical circle has a diameter of nine and one half inches, and is set by means of the clamp, v, and the tangent-screw, w; when, however, the required reading has been obtained, the more powerful clamp, y, is applied, and the lower clamp is released. There is thus obtained a greater certainty of the constancy of the angle between levels and telescope. After the vertical circle is set the telescope is clamped at approximately the proper inclination by r, and the bubbles are then centered by the tangent-screw, s.

The eye-end is somewhat complicated. To the rear of the eye-piece is a focal scale, not visible in the drawing, ξ being the focus-clamp. The micrometer-head is at θ, and the field is centered by the opposite screw, λ. The collimation may be adjusted by two opposing screws, one of which is shown at v, and the inclination of the micrometer-head is also controlled by two opposing, of which k is one. The eye-piece itself, η, contains a reversing prism, so that the micrometer thread may be set apparently vertical (preferably), no matter what the inclination of the telescope may be. Furthermore, an ingenious device has been added by which the thread may be apparently reversed 180° by simply turning the outer part of the eye-piece from one stop to another, which is 90° distant. This outer part of the eye-piece is held in place by slight friction with the inner part; the latter is in turn held by somewhat greater friction to the telescope tube, so that the outer part may be turned without disturbing the inner, and either may be moved without changing the focus. The method of observing with this eye-piece is to set the outer part against one of its stops, then to turn the inner part till the microm-

eter thread appears vertical. When the star comes into view, two bisections are made before it reaches the middle of the field. The outer tube of the eye-piece is then turned against its other stop, and two more bisections are made before the star leaves the field. The effect is to make the star appear and disappear in the same part of the field, either at the top or at the bottom. From even the somewhat limited experience which the writer has had with this eye-piece, he is able to state that it constitutes no small improvement; not only on account of the greater accuracy which comes from holding the head in a comfortable position, but also because personality, in always setting the wire too far to the right, say, is thus eliminated from the measurements of each star.

In order to avoid as much labor as possible in determining the azimuths, collimation, etc., of the instrument, a meridian-mark is used. This consists of two targets separated by twice the eccentricity of the telescope, and mounted on a pier not less than fifty yards distant either to the north or to the south of the zenith-telescope. One of the targets is placed exactly in the meridian of the telescope when the latter is east of the vertical axis, and the other is to be in the meridian when the telescope is west. Their positions may be verified from time to time by star-transits. In order that the targets may be brought into focus without disturbing the collimation, an auxiliary lens is placed between the objective and eye-piece, and as near the latter as practicable. It is shunted into the optical axis by means of μ, and works against a stop so as always to come to the same place. The position of the lens is such as to make the likelihood of a change in collimation a minimum; but it should be remarked that this change need not be small if it remain constant during the short period between two consecutive tests of the targets for position. The presence of the auxiliary lens has suggested a method for determining the progressive and periodic errors of the micrometer-screw, which will be tried at Ukiah as soon as opportunity offers. A vertical scale may be supported on the meridian-mark pier, with spaces between its divisions to correspond with one turn of the micrometer-screw. The progressive errors of the screw and the division errors of the scale may then be determined simultaneously by the method variously accredited to GILL, LORENTZEN, LEMAN, and THRESSIN.* The periodic errors may be found by

* A good exposition of this method has been given by HAROLD JACOBY, in the *American Journal of Science*, for May, 1896.

direct readings of a smaller scale, whose errors have first been determined by the above method. The writer believes that in this way more accurate results can be obtained in a given time than by employing circumpolar elongations. Besides, this work may be executed in the daytime or on cloudy nights.

As shown in the picture, the telescope is provided with electric illumination for the field, but this may very quickly be changed for oil or other illumination.

The chief constants of the instruments are as follows: Focal length, 51 inches; aperture, 4¼ inches; magnifying power, 104; one turn of micrometer-screw, 40″; least direct reading of micrometer, 0″.4; least direct reading of levels, 1″.0.

The micrometer-head may thus be read by estimation to 0″.04, and the levels to 0″.10.

The instrument was made by WANSCHAFF, of Berlin, with the optical parts by ZEISS, of Jena, and the levels by REICHEL, of Berlin.

IV. THE OBSERVATORY.

The following very brief description applies especially to the station at Ukiah; but the others are not different in any essential, except that perhaps some of the foreign observatories have been built of iron. All three* in this country are of wood.

The zenith-telescope pier is of brick, twenty-three inches square, and rests on a brick foundation four feet deep and five feet square. The floor and walls of the observatory are supported by a brick foundation-wall, which is as deep as the foundation for the pier; between the two is an air-space. On the outer edge of the foundation-wall rests a high wooden lattice thirteen feet square; on the inner edge is the observatory wall proper, leaving a well-ventilated space all around the observatory. The roof is made double, and is provided with ventilators projecting into the open air. The walls of the observatory are also pierced by four ventilators, two up high and two down low, so that the interior is

* The following details concerning the station at Cincinnati are taken from a letter from Professor PORTER, dated October 17, 1899: "A small observatory, modeled after the plans sent from Potsdam, but constructed of wood, was erected on the grounds of the Cincinnati Observatory, $19^{m}.0$ west and $14^{m}.6$ south of the center of the dome. The Superintendent of the United States Coast and Geodetic Survey kindly loaned us a zenith-telescope for the prosecution of this work. It is one of WANSCHAFF'S instruments, constructed on the same general lines as the somewhat larger instruments built for the four main stations. The focal length is $1^{m}.00$, aperture 81^{mm}, magnifying power 100. . . . It was not convenient to erect a collimator, and the instrumental constants are controlled by observations of stars. Practically, however, this gives no trouble, as the instrument is very steady. The use of a reversing prism was also found to be impossible with the fainter stars."

kept dry and at the same temperature as the atmosphere outside. The roof of the observatory is in two parts, one of which rolls east and the other west, leaving a clear opening of six feet. While observing, all other openings are closed, and if the wind is blowing too hard, the roof-opening is also contracted. The meridian-mark is viewed through a north door. The pier on which the mark is mounted is sheathed with tinning and protected by a wide lattice structure, so as to guard against warpings from the direct rays of the sun. A pendulum-clock, beating seconds, a self-registering barometer, and several other minor instruments have been provided for each station.

UKIAH, CALIFORNIA, 1899, Nov. 20.

THE *PERSEID* RADIANT.

By W. H. S. MONCK.

Mr. DENNING'S recent paper in the *Memoirs of the Royal Astronomical Society* has, I think, placed beyond doubt that in the vast majority of cases meteors come from the same radiant point at different seasons of the year. The coincidences are far too numerous and too close to be the result of chance. There must, generally speaking, be some physical connection between the various meteors which Mr. DENNING classes together, and the duty of the physicist is not to ignore this fact, but to explain it. Theoretically,—I mean in accordance with the current theory,—all showers which last for more than one night ought to shift. But they do not. Mr. DENNING mentions but two shifting radiants — the *Lyrids* and the *Perseids* — and he is doubtful as to whether the apparent shifting of the former is real. He further points out that there is a permanent, or stationary, radiant almost coincident with both. This is a significant fact, and throws a difficulty in the way of proving the actual shifting. At all events, Mr. DENNING'S catalogue justifies the assertion that stationary radiation is the rule, and shifting radiation the exception — if indeed there be any exception. This is the exact opposite of what the current theory would lead us to expect; and consequently the current theory must, I apprehend, be wrong.

My main object is, however, to deal with the *Perseid* radiant, which is the stronghold of all who believe in shifting radiants,